Impact of the SRP model on CODE's 5-system orbit and clock solution for the MGEX

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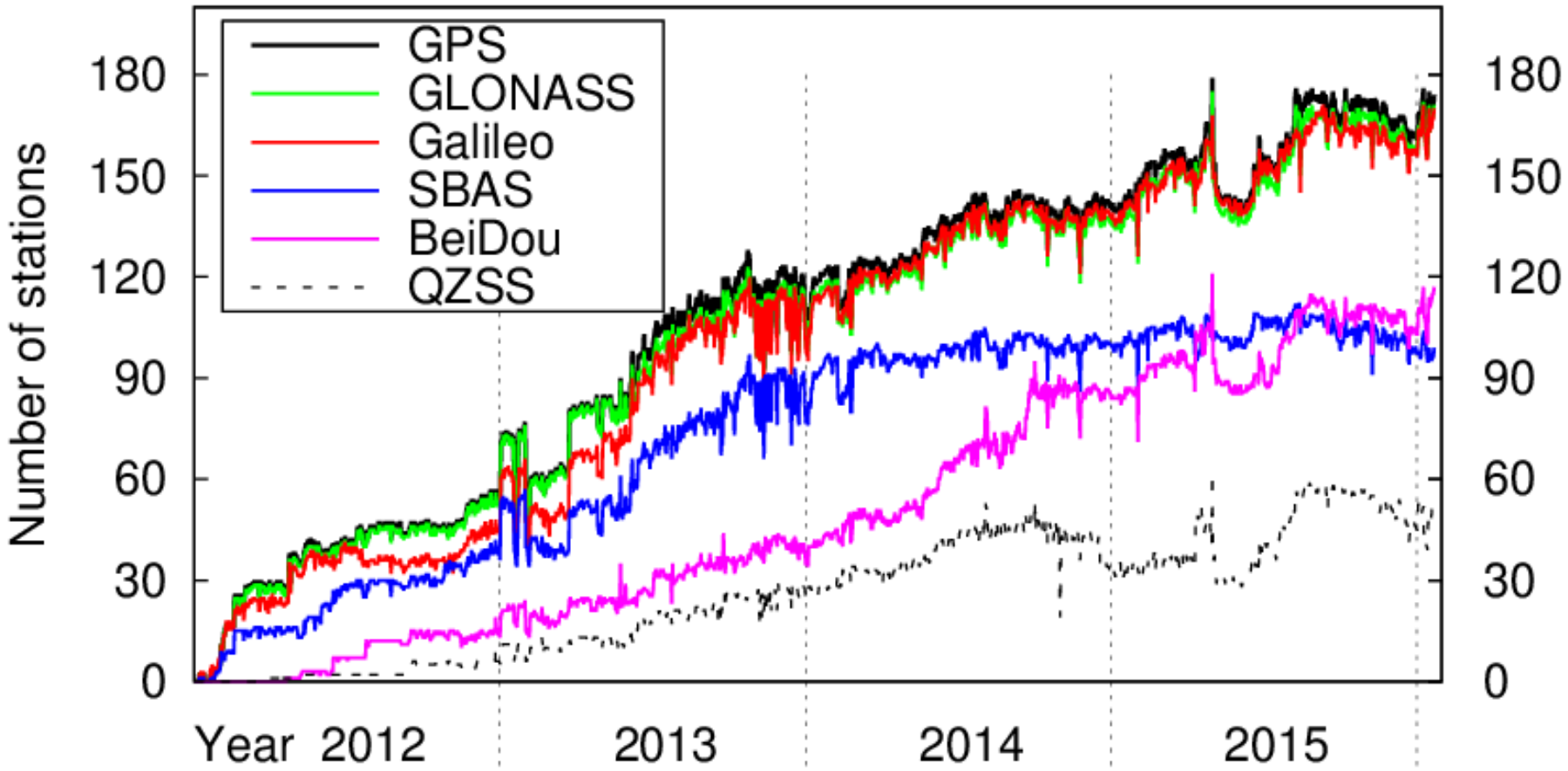
MGEX data monitoring

Number of stations providing daily RINEX3 files and included in CODE‘s raw data monitoring (data sources: IGS-MGEX and EPN)



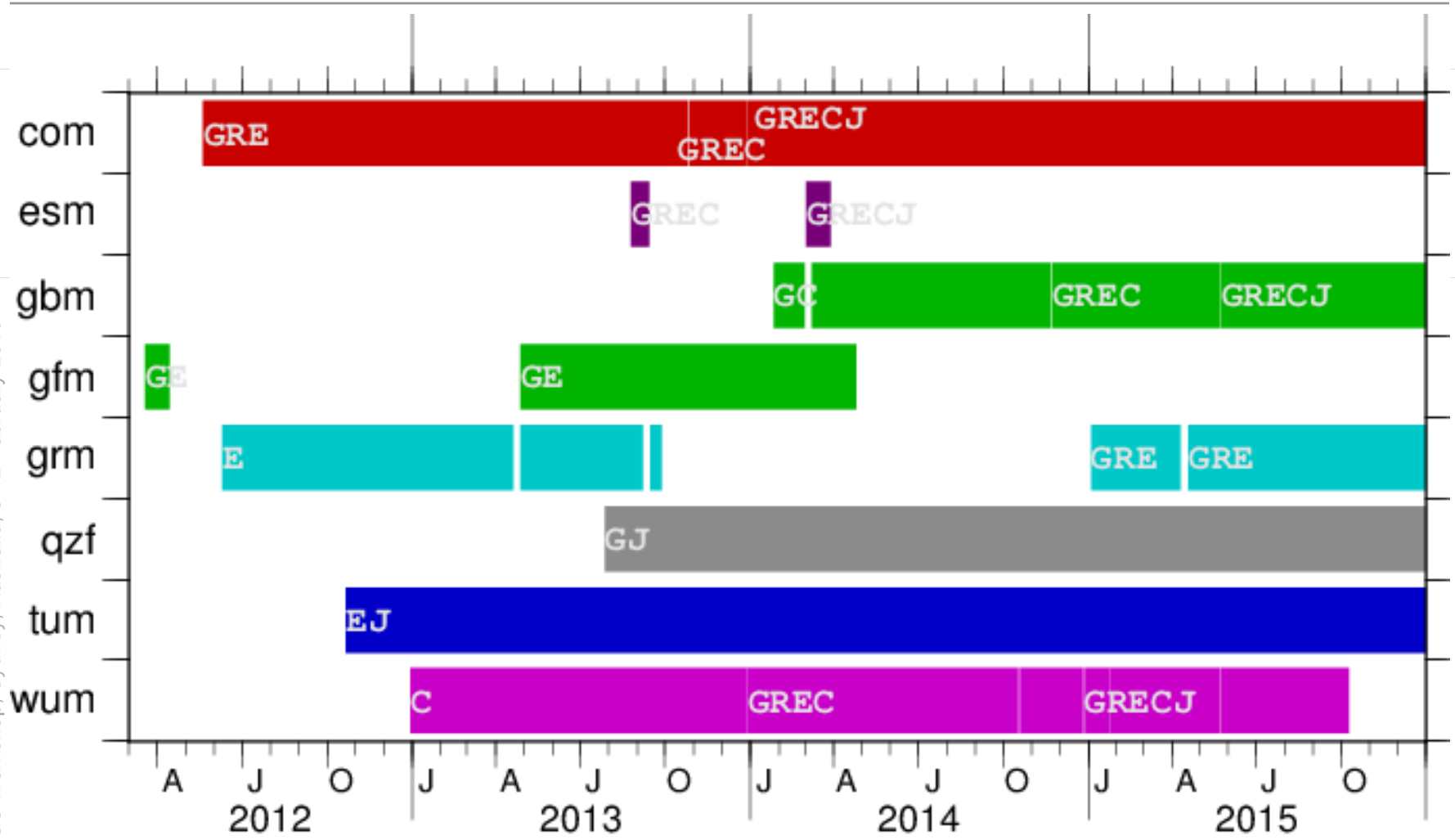
CODE MGEX orbit solution

GNSS considered:	**GPS + GLONASS + Galileo + BeiDou** (MEO+IGSO) + **QZSS** (≈70 SV)
Processing mode:	Post-processing (≈2 weeks latency)
Timespan covered:	GPS-weeks 1689 - today
Number of stations:	130 (GPS), 110 (GLONASS), 85 (Galileo); 55 (BeiDou); 20 (QZSS)
Processing scheme:	**Double-difference** network processing (observable: phase double differences)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) Galileo; B1 (L1) + B2 (L7) BeiDou
Orbit characteristic:	3-day long arcs; SRP: ECOM / ECOM2 (since 2015)
Reference frame:	IGS08 (until week 1708); IGb08 (since week 1709)
IERS conventions:	IERS2003 (until 1705); IERS2010 (since 1706)
Product list:	Daily orbits (SP3) and ERPs
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/ and **ftp://ftp.unibe.ch/aiub/CODE_MGEX/**
Designator:	comwwwwd.???.Z

CODE MGEX clock solution

GNSS considered:	**GPS + GLONASS + Galileo + BeiDou + QZSS** (≈70 SV)
Processing mode:	Post-processing (≈2 weeks latency)
Timespan covered:	GPS-weeks 1710 - today
Number of stations:	130 (GPS), 35 (GLO), 45 (Galileo); 50 (BeiDou); 20 (QZSS)
Processing scheme:	**Zero-difference** processing (observable: code+phase undifferenced)
Signal frequencies:	L1+ L2 (GPS + GLO+ QZSS); E1 (L1) + E5a (L5) Galileo; B1 (L1) + B2 (L7) BeiDou
A priori information:	Orbits, ERPs, coordinates, and troposphere from CODE MGEX orbit solution introduced as known
Reference frame:	IGb08
IERS conventions:	IERS2010
Product list:	Epoch-wise (300s) satellite and station clock corrections in daily clock RINEX files; daily inter-system biases for mixed stations in Bernese DCB and BIAS-SINEX format
Distribution:	ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/ and **ftp://ftp.unibe.ch/aiub/CODE_MGEX/**

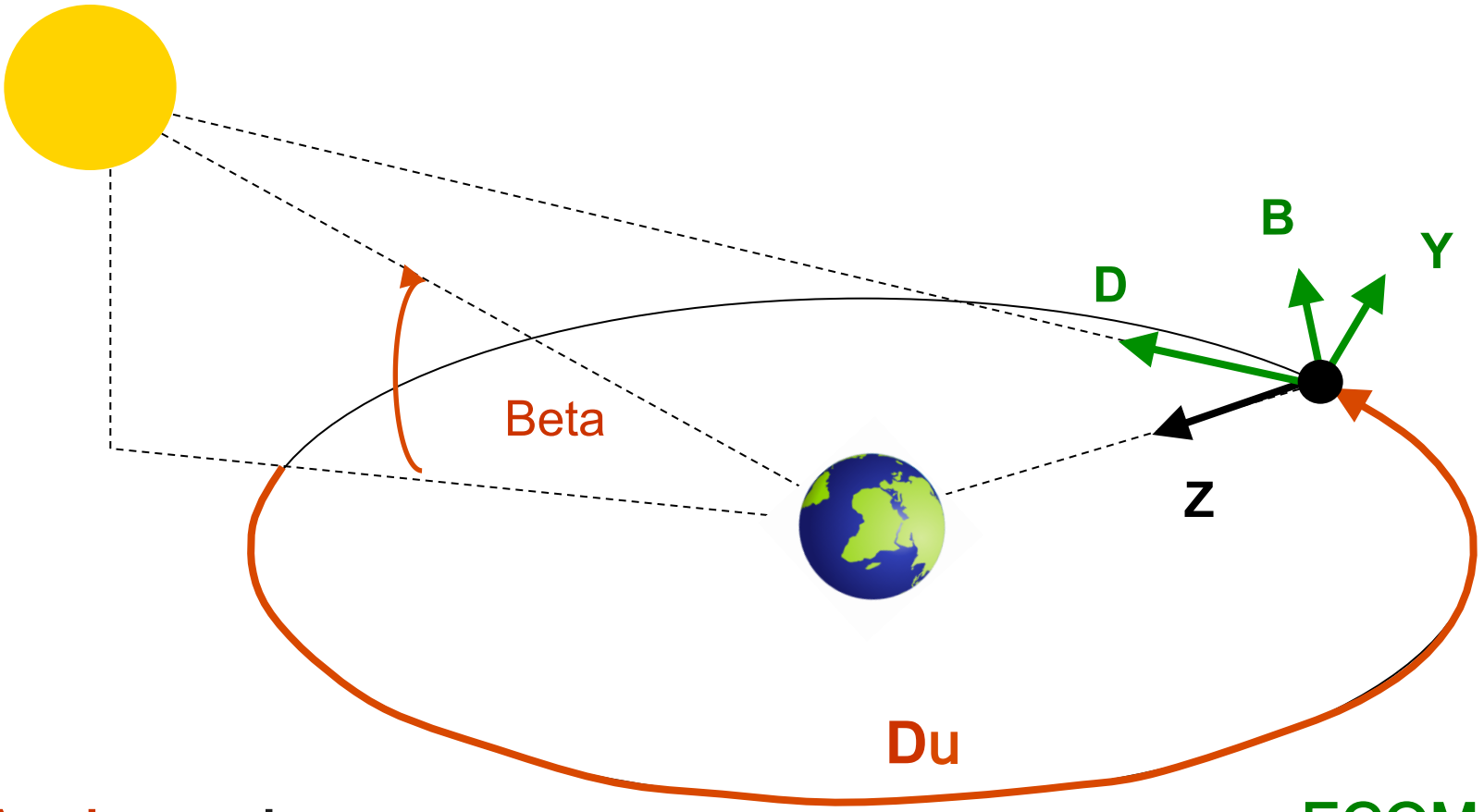
MGEX products availability



Status: 01-Jan-2016

Satellite system IDs according to the content of the precise orbit files at ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/

Orbit description and Yaw attitude



Angles and vectors:

Beta: Elevation of Sun above orbital plane

Du: Argument of latitude

Z: Direction satellite -> Earth (antenna direction)

ECOM axes:

D: Direction satellite -> Sun

Y: Solar panel axis

B: Third ECOM axis

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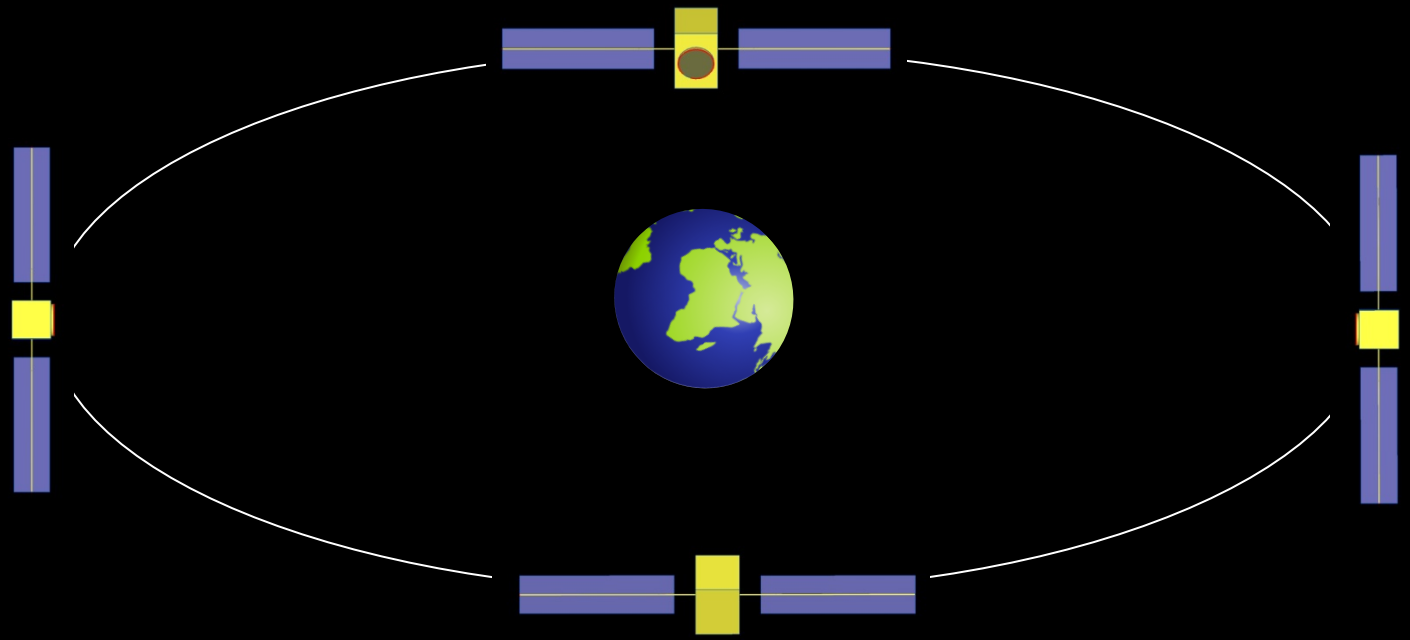
Solar radiation pressure

Satellite cross-section as seen from the Sun (Beta ≈ 30°) during one orbital revolution:

=> solar panel area does not change



=> but: cross-section of long satellite bodies w.r.t. the Sun varies

New Empirical CODE radiation pressure Model

- MGEX-reprocessing for 2014 using ECOM (5 RPR par.; Beutler et al., 1994, Springer et al., 1999) vs. ECOM2 (9 RPR par., Arnold et al., 2015)
- Validation with SLR residuals and satellite clock corrections
- The new ECOM takes into account the periodically changing cross section of elongated satellite bodies wrt. the Sun

=> Improvements expected for Galileo, GLONASS, QZSS

ECOM1 (old):

$$D(u) = D_0$$

$$Y(u) = Y_0$$

$$B(u) = B_0 + B_C \cos(u) + B_S \sin(u)$$

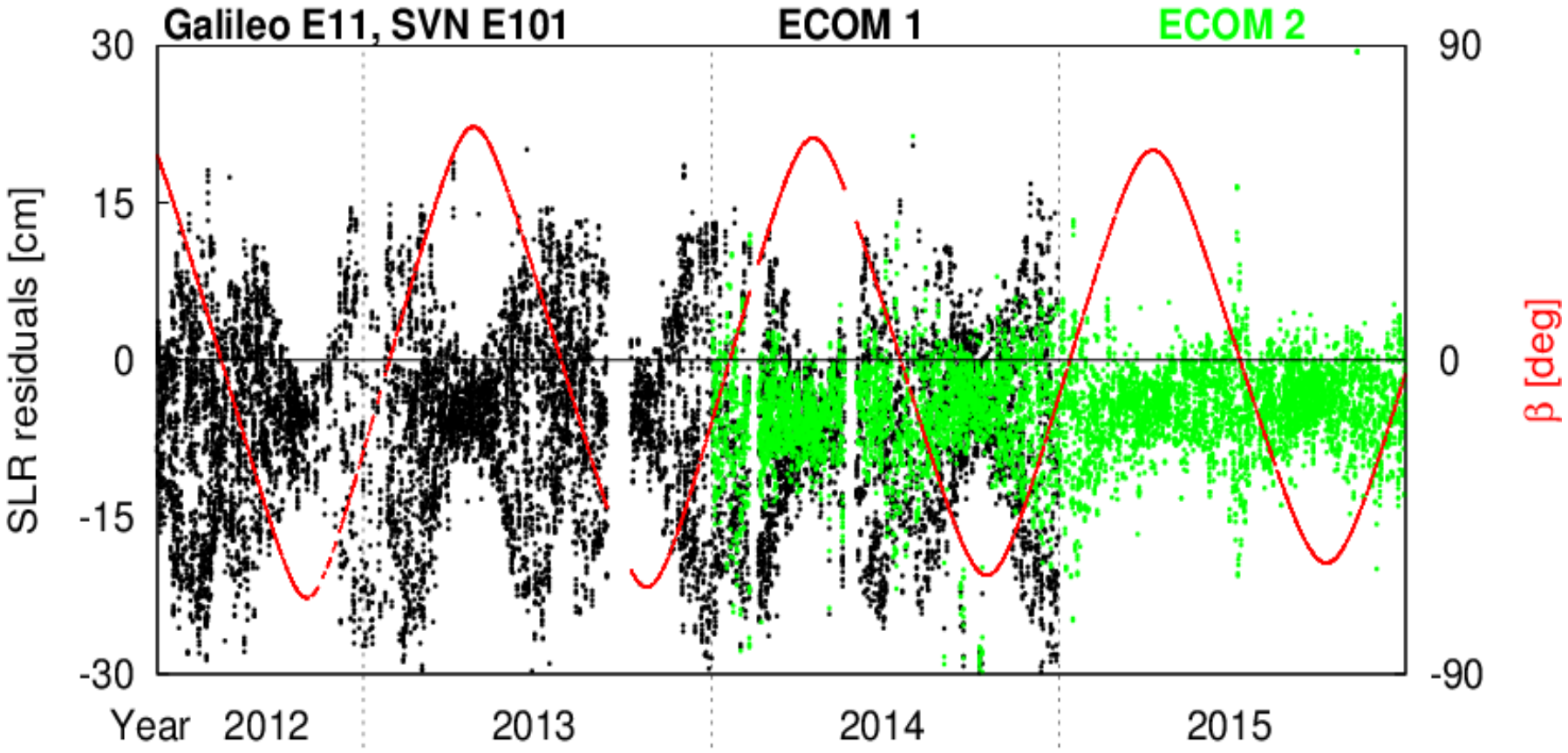
ECOM2 (new):

$$D(u) = D_0 + D_{2C} \cos(2Du) + D_{2S} \sin(2Du) + D_{4C} \cos(4Du) + D_{4S} \sin(4Du)$$

$$Y(u) = Y_0$$

$$B(u) = B_0 + B_C \cos(Du) + B_S \sin(Du)$$

Impact of new ECOM on Galileo orbits



⇒ Significant reduction of size and dependency of SLR residuals on the Beta-angle

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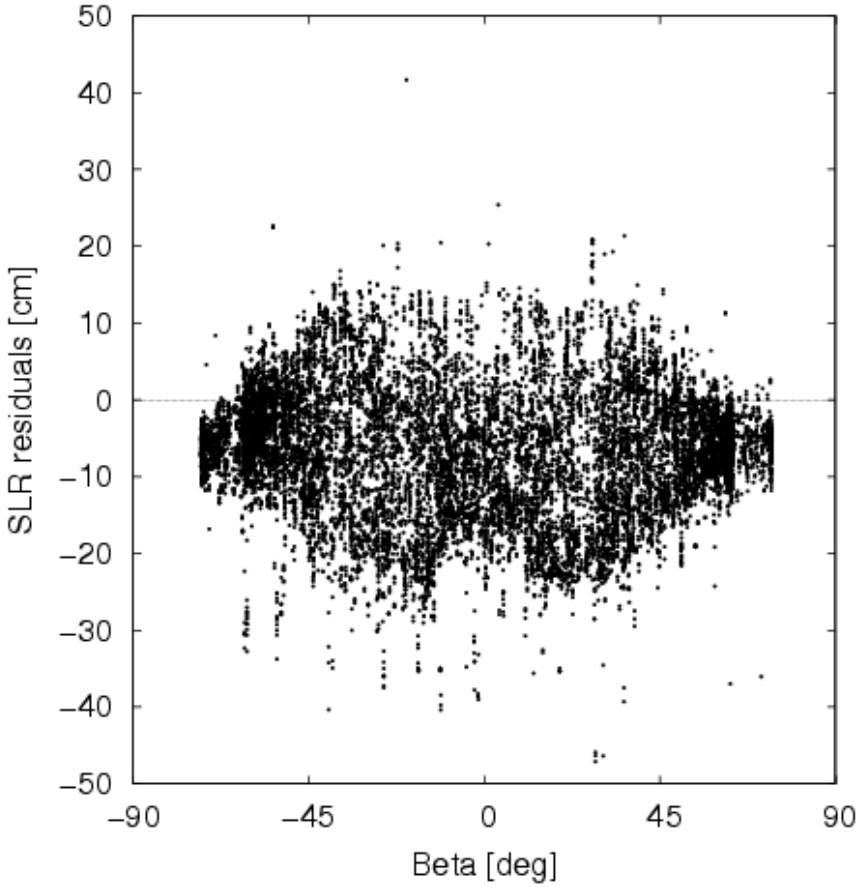
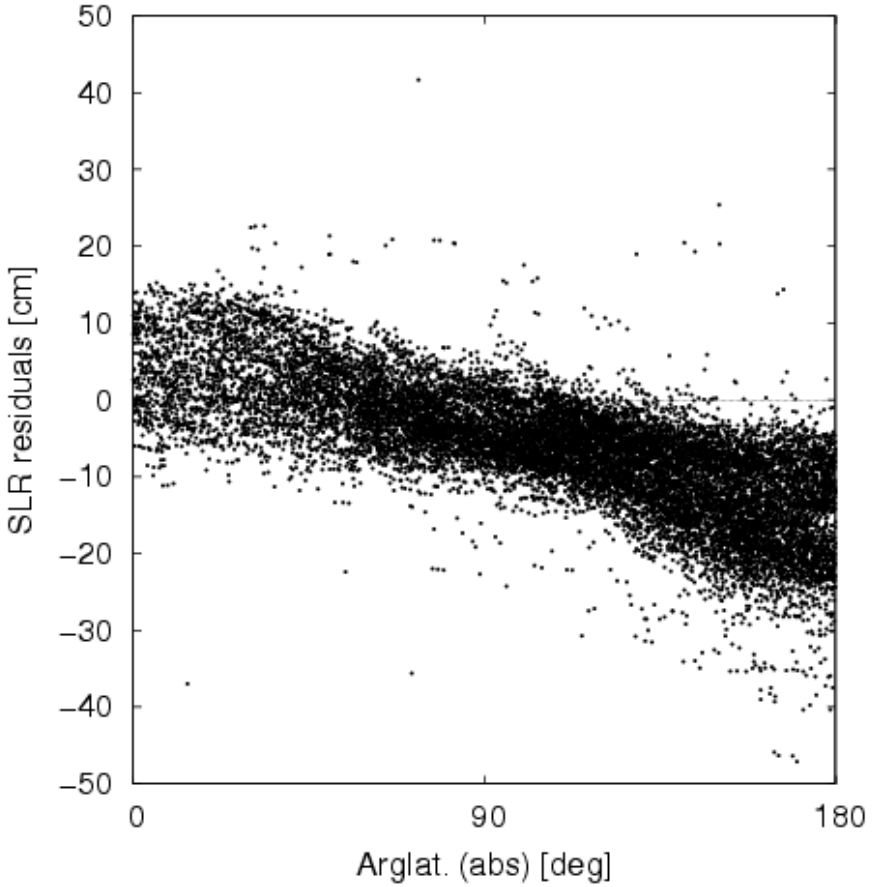
Impact of new ECOM on Galileo orbits





ECOM1 (all Galileo satellites):

⇒ SLR residuals of 2014 are large at small and medium Beta angles and with argument of latitude around 0° and ±180°

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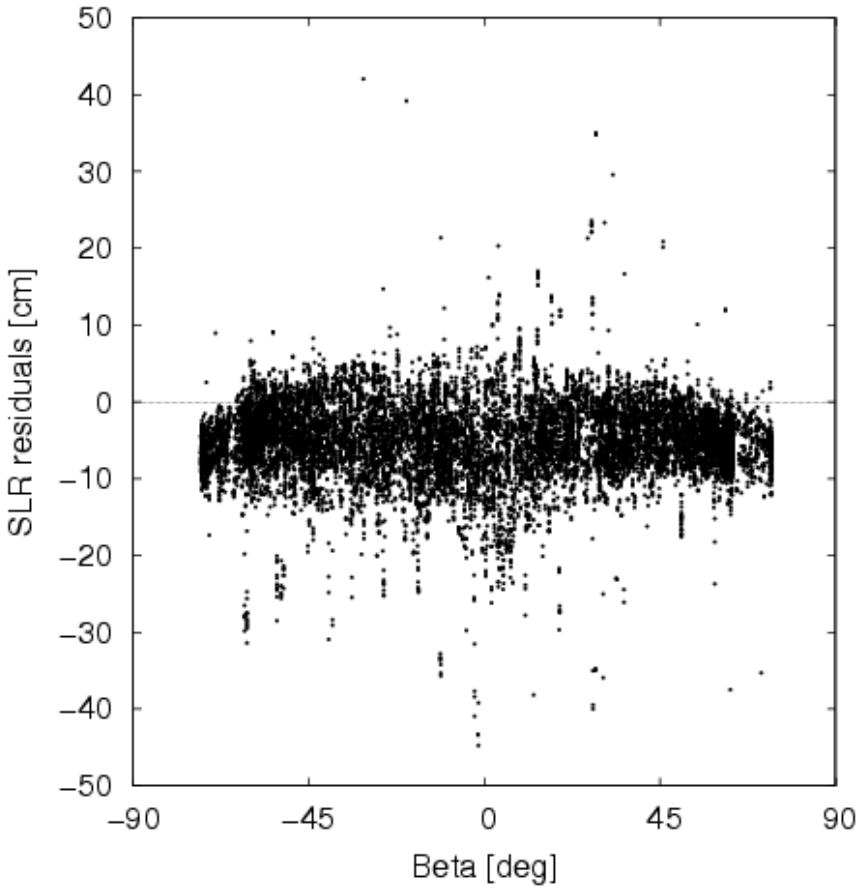
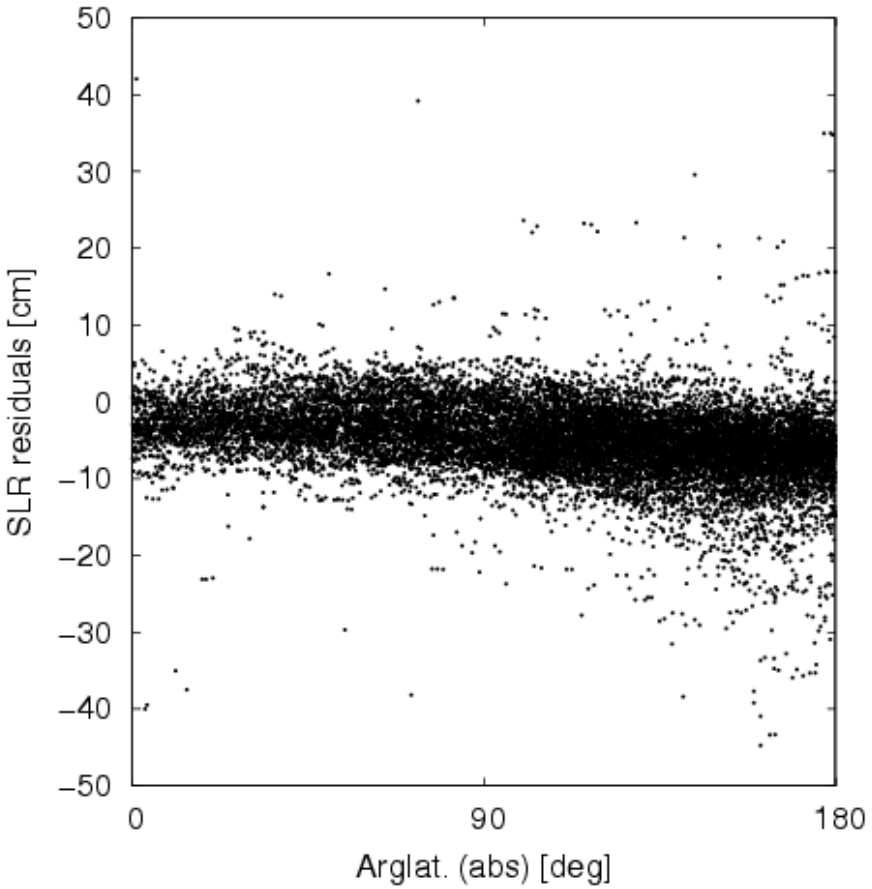
MGEX, IGS Work

Impact of new ECOM on Galileo orbits





ECOM2 (all Galileo satellites):

⇒ Systematics in the SLR residuals are significantly reduced

⇒ Significant SLR offset remains

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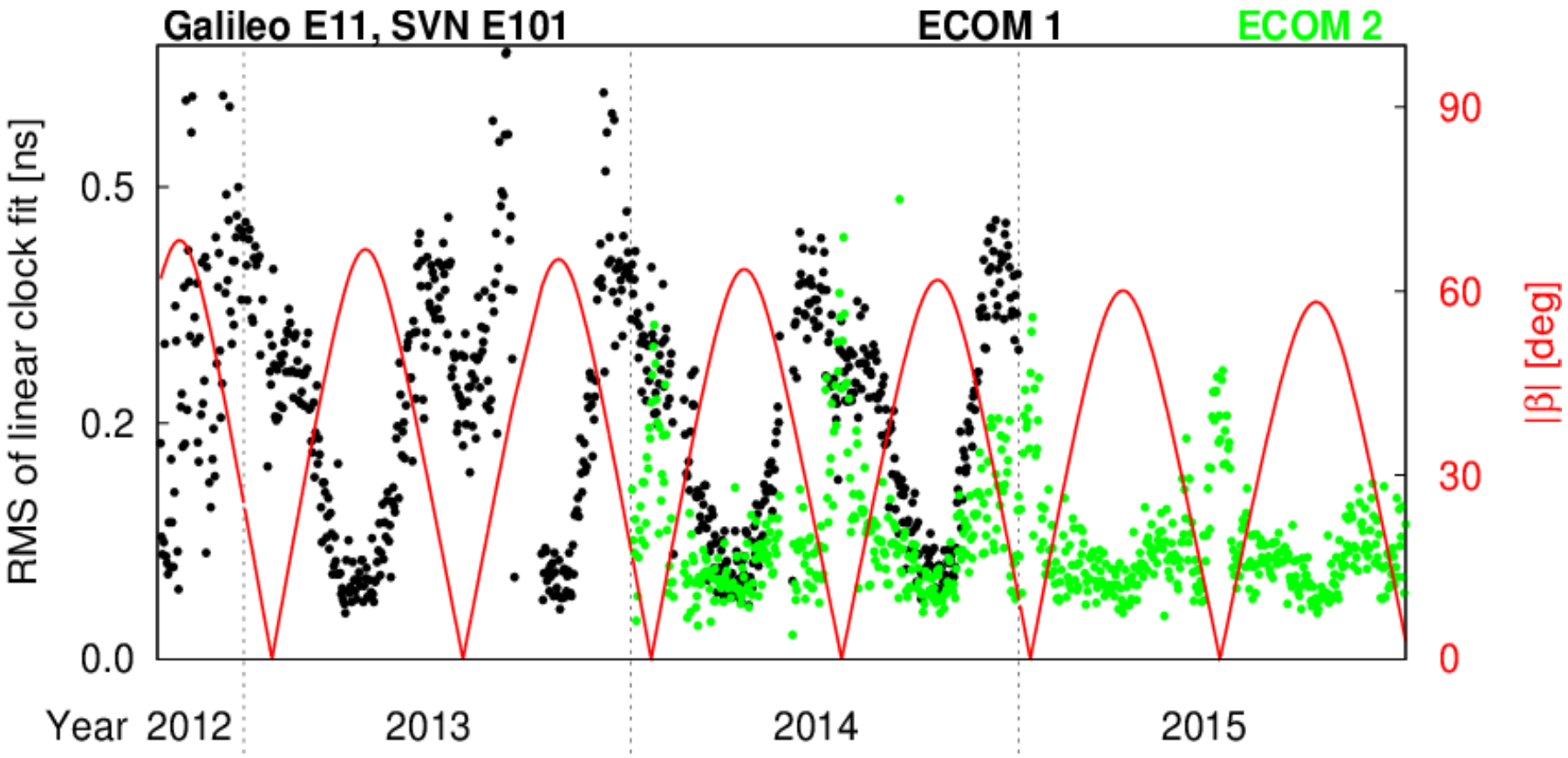
MGEX, IGS Work

Impact of new ECOM on Galileo clock corrections



⇒ Significant reduction of Beta angle dependency

⇒ Pronounced signal remains during eclipse season or close-by (impact of mis-modelled attitude?)

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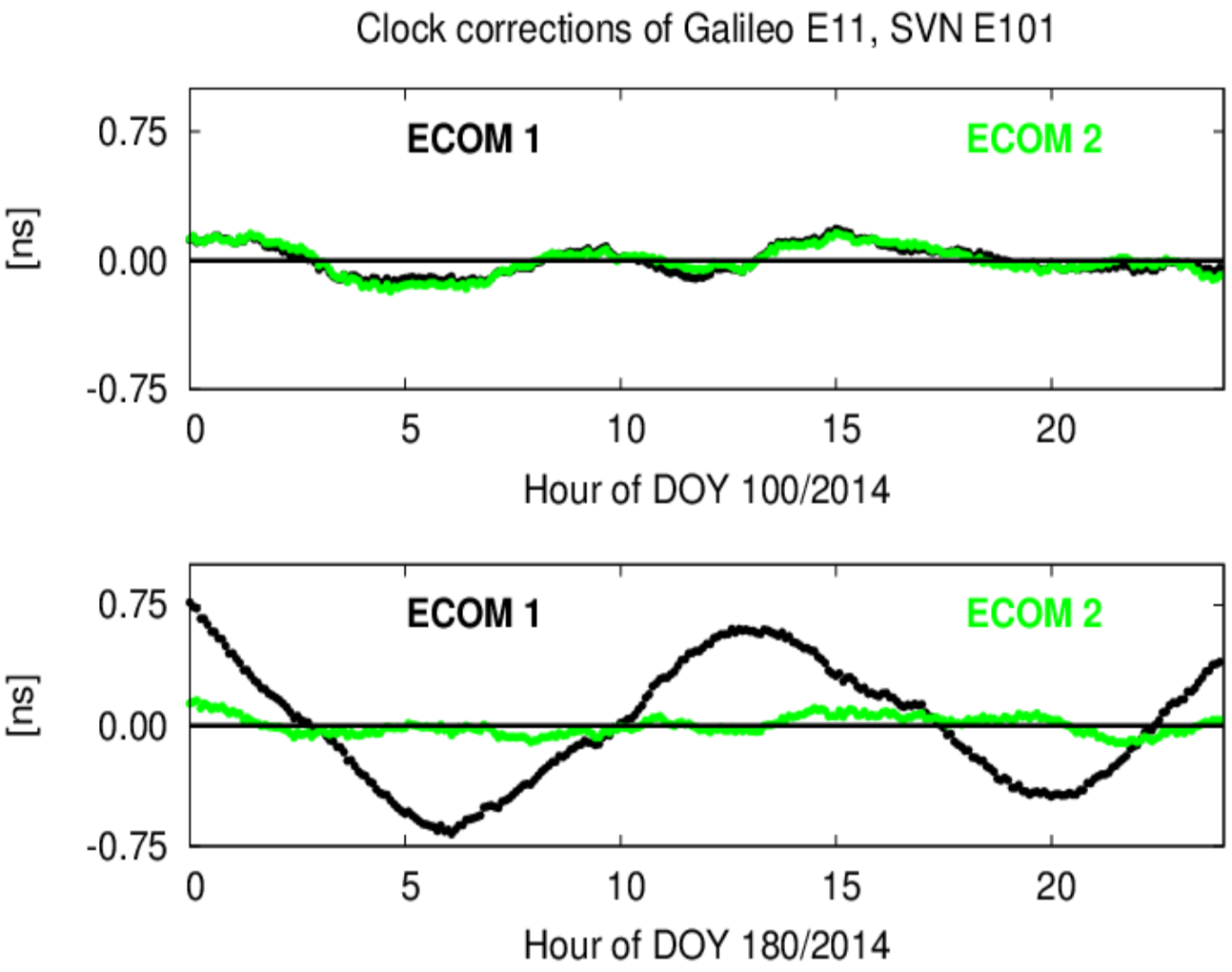
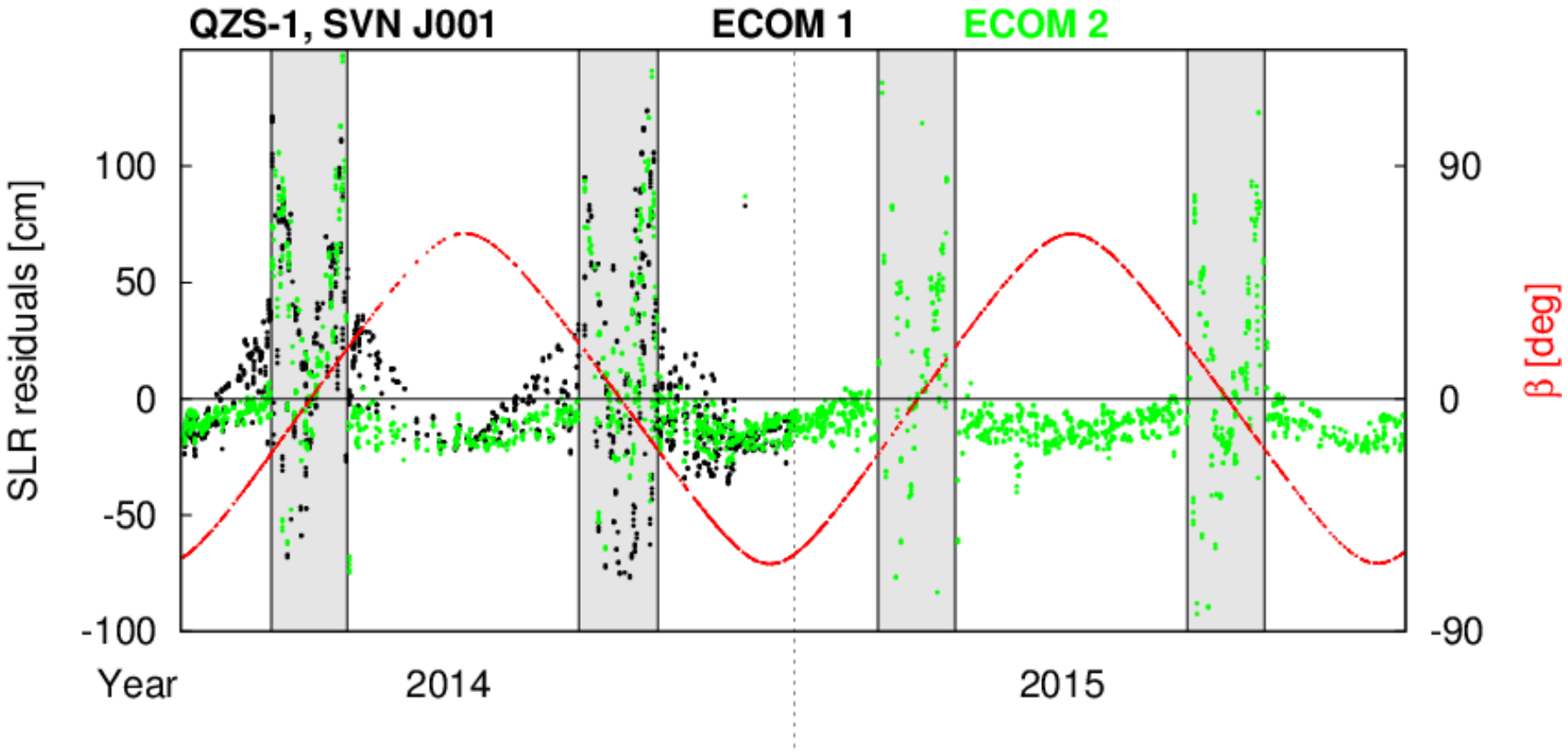
Impact of new ECOM on Galileo clock corrections



Large beta-angle:
=> Clock signal has small amplitude (about ±0.15 ns)

Small beta-angle:
=> Periodic signal caused by mis-modelled orbit (ECOM1)
=> Significant reduction of signal amplitude from ±0.75 ns to ±0.15 ns (ECOM2)

Impact of new ECOM on QZSS orbits



⇒ ECOM2 reduces dependency on Beta angle

⇒ Significant SLR offset remains

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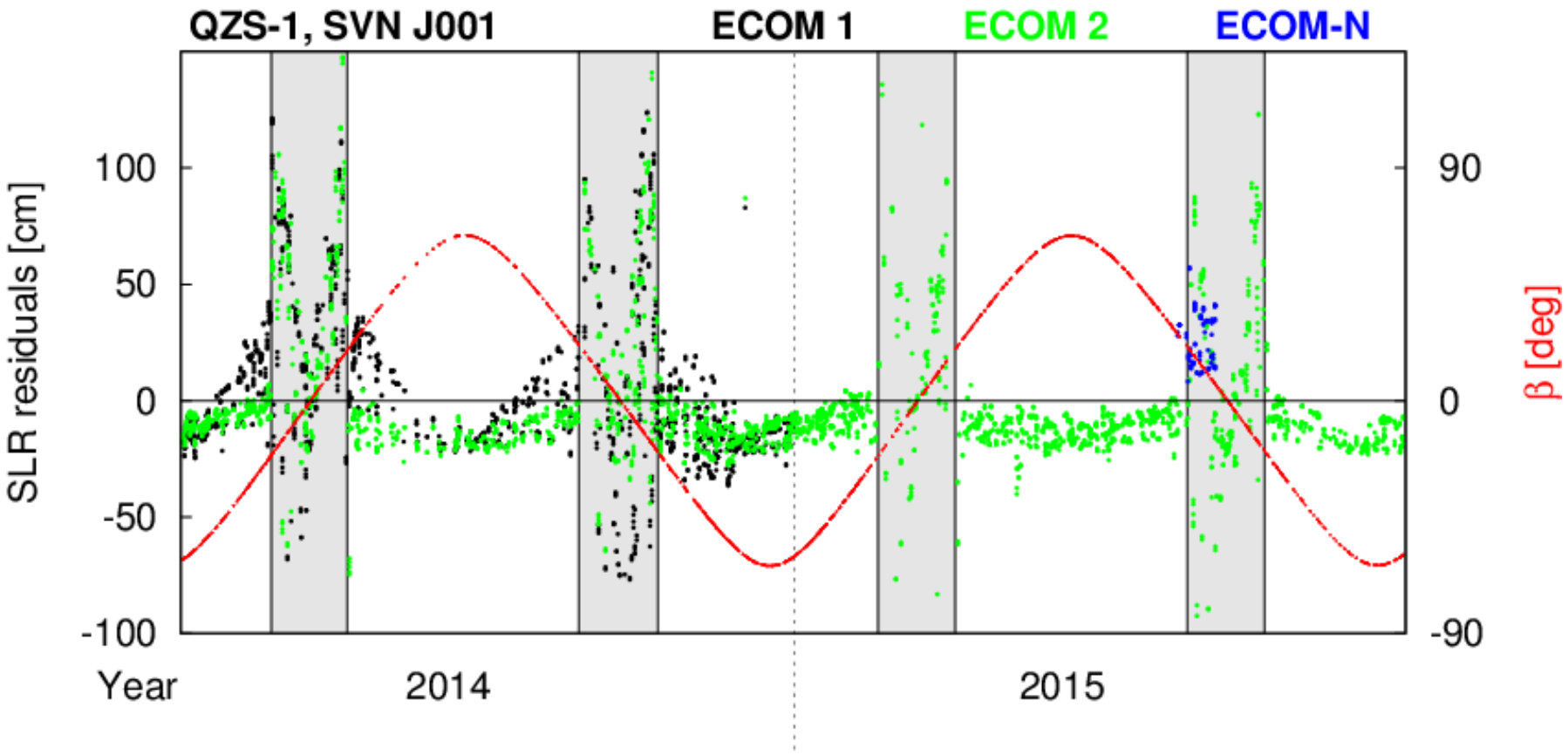
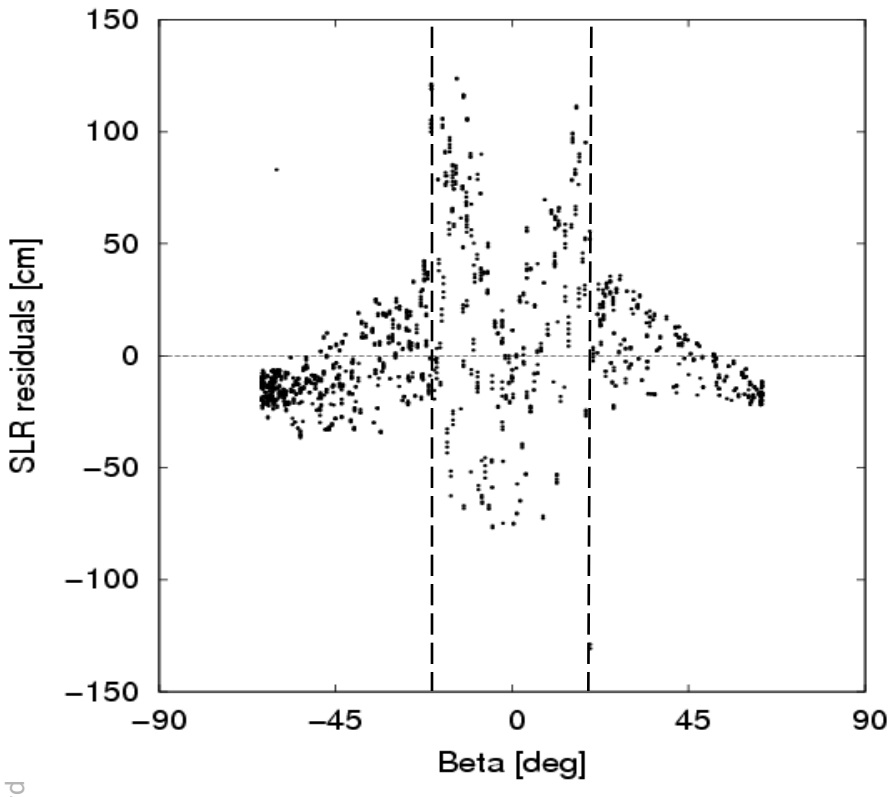
Impact of new ECOM on QZSS orbits

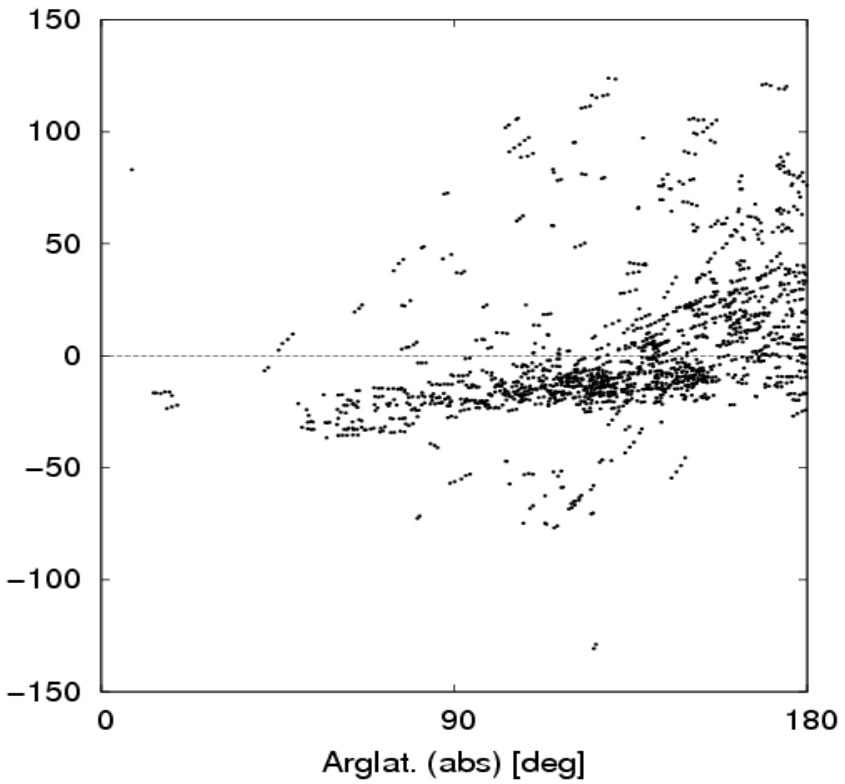


⇒ Large orbit errors occur at |ß| < 20° (marked grey)

⇒ Test of new ECOM version suited for orbit normal attitude mode

Impact of new ECOM on QZSS orbits



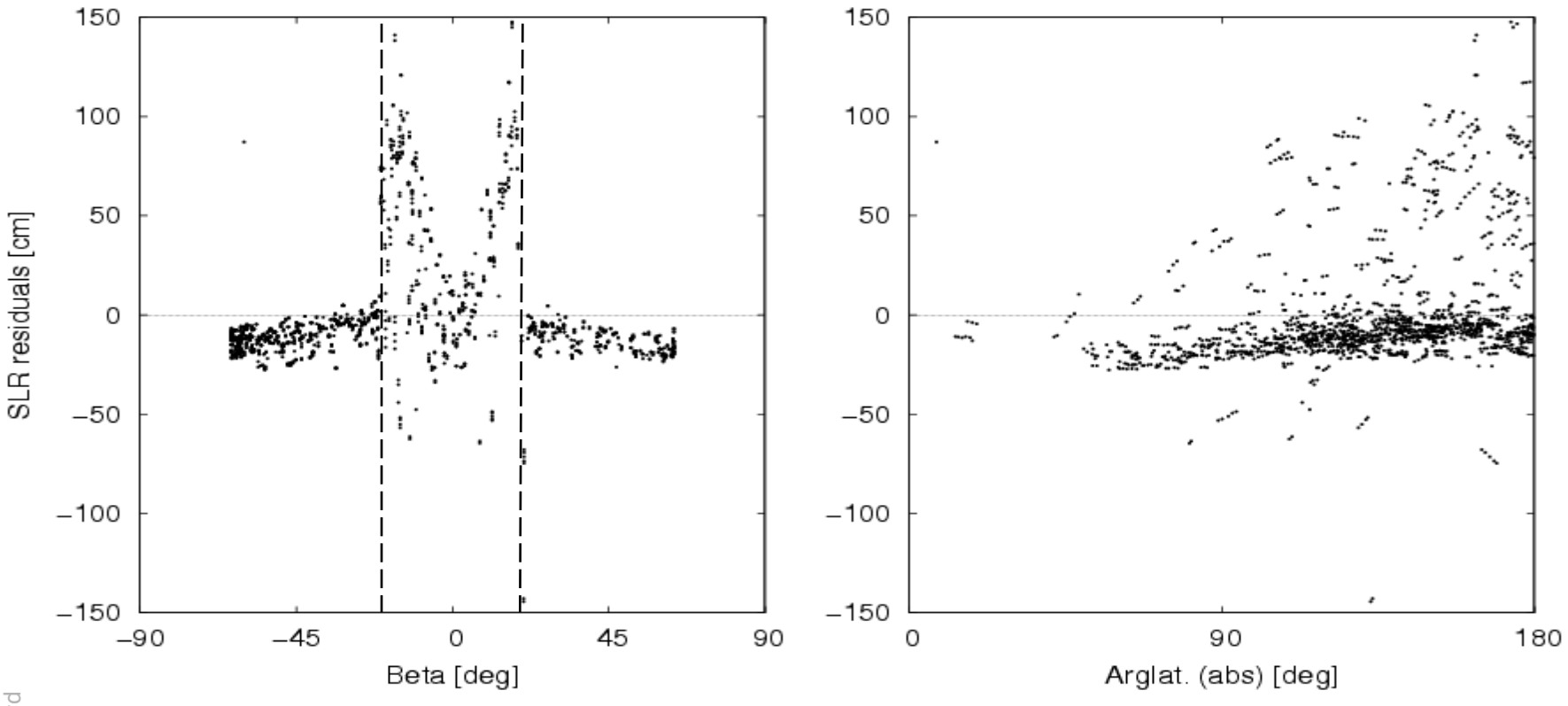


ECOM1:

⇒ |ß| < 20°: SLR residuals of 2014 are dominated by not correctly considered orbit normal attitude mode

⇒ |ß| > 20°: correlation with Beta angle and argument of latitude

Impact of new ECOM on QZSS orbits



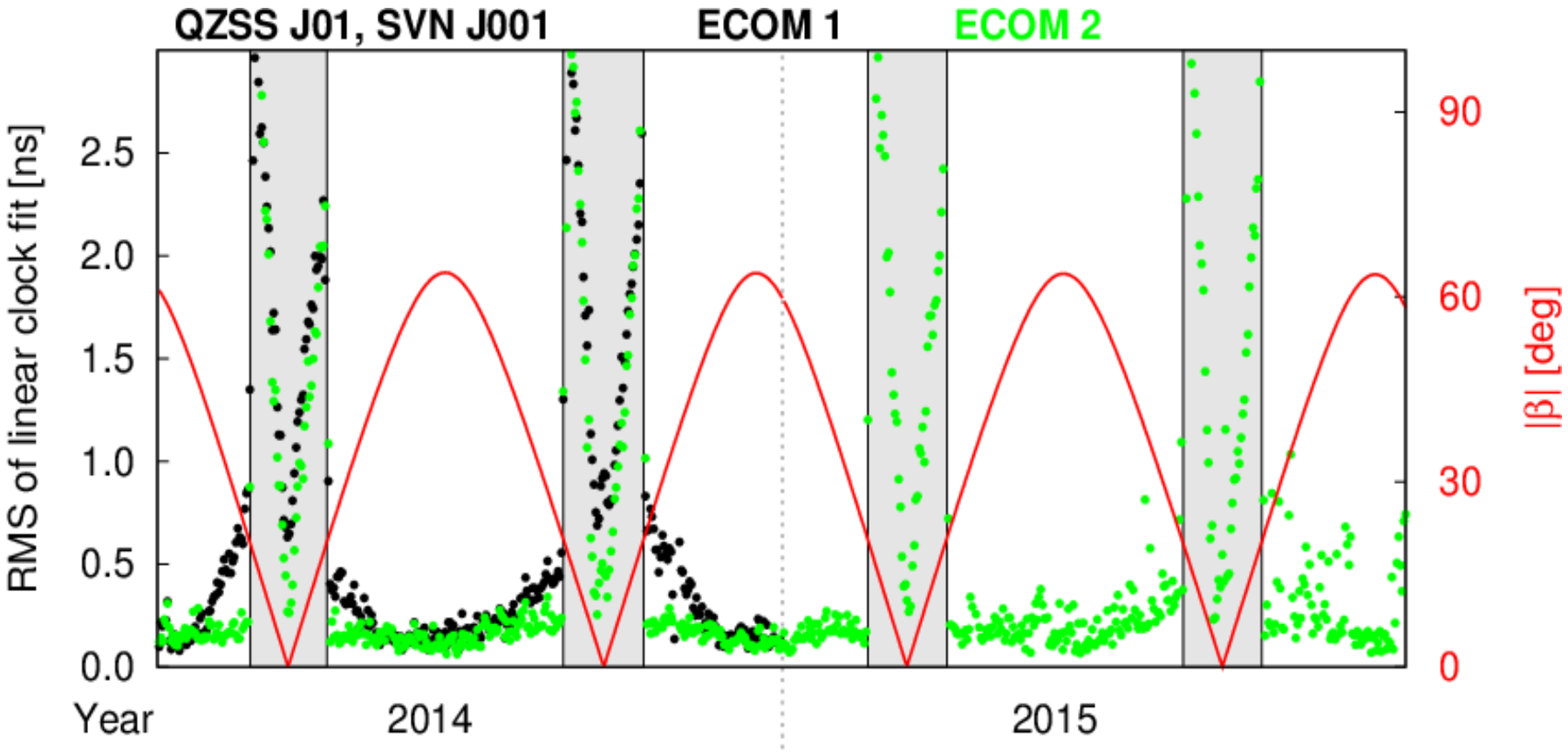
ECOM2:

⇒ |ß| < 20°: SLR residuals remain large

⇒ |ß| > 20°: systematics in the SLR residuals are reduced

⇒ SLR offset remains

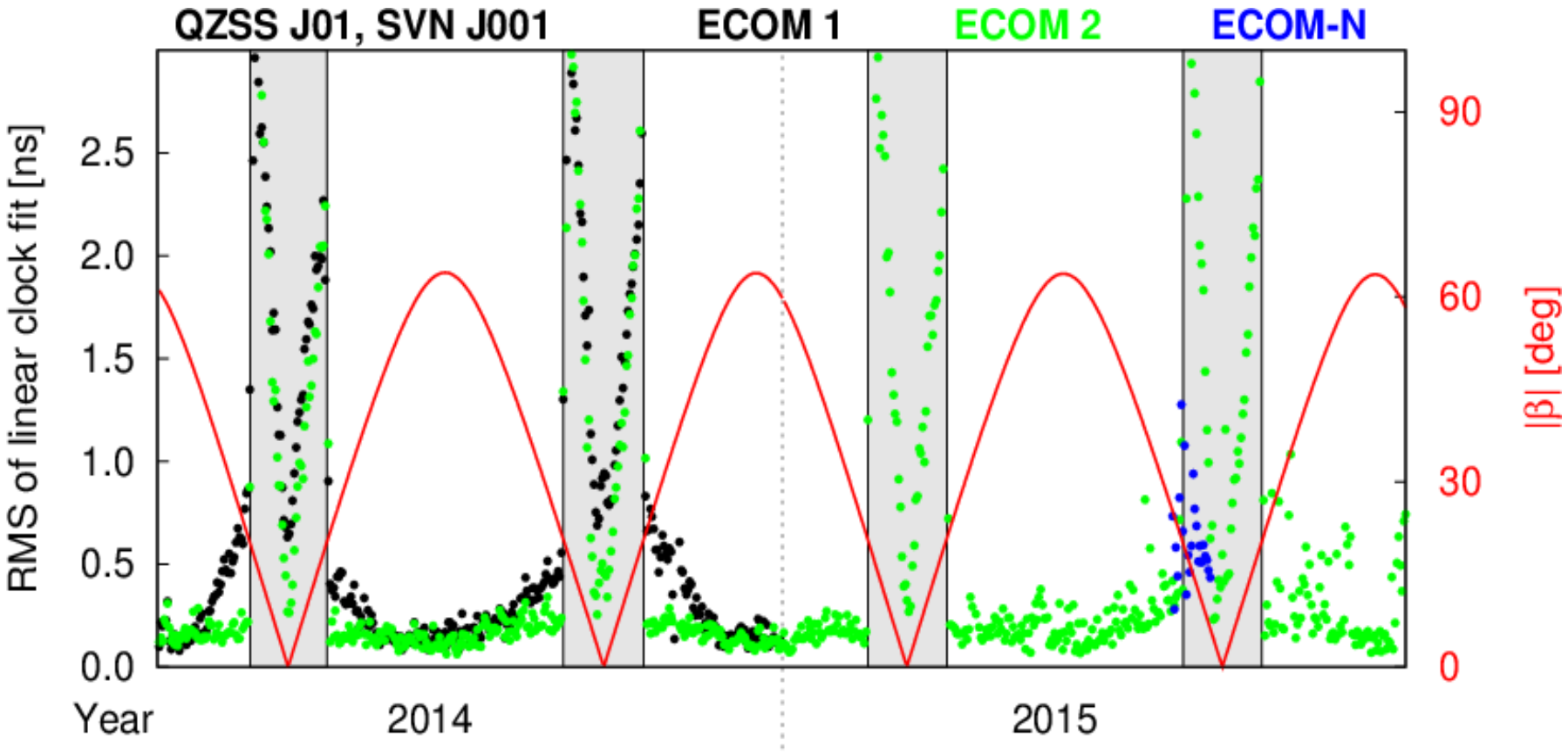
Impact of new ECOM on QZSS clock corrections



⇒ Significant reduction of Beta angle dependency at Yaw attitude thanks to ECOM2

⇒ Large errors remain at orbit normal attitude

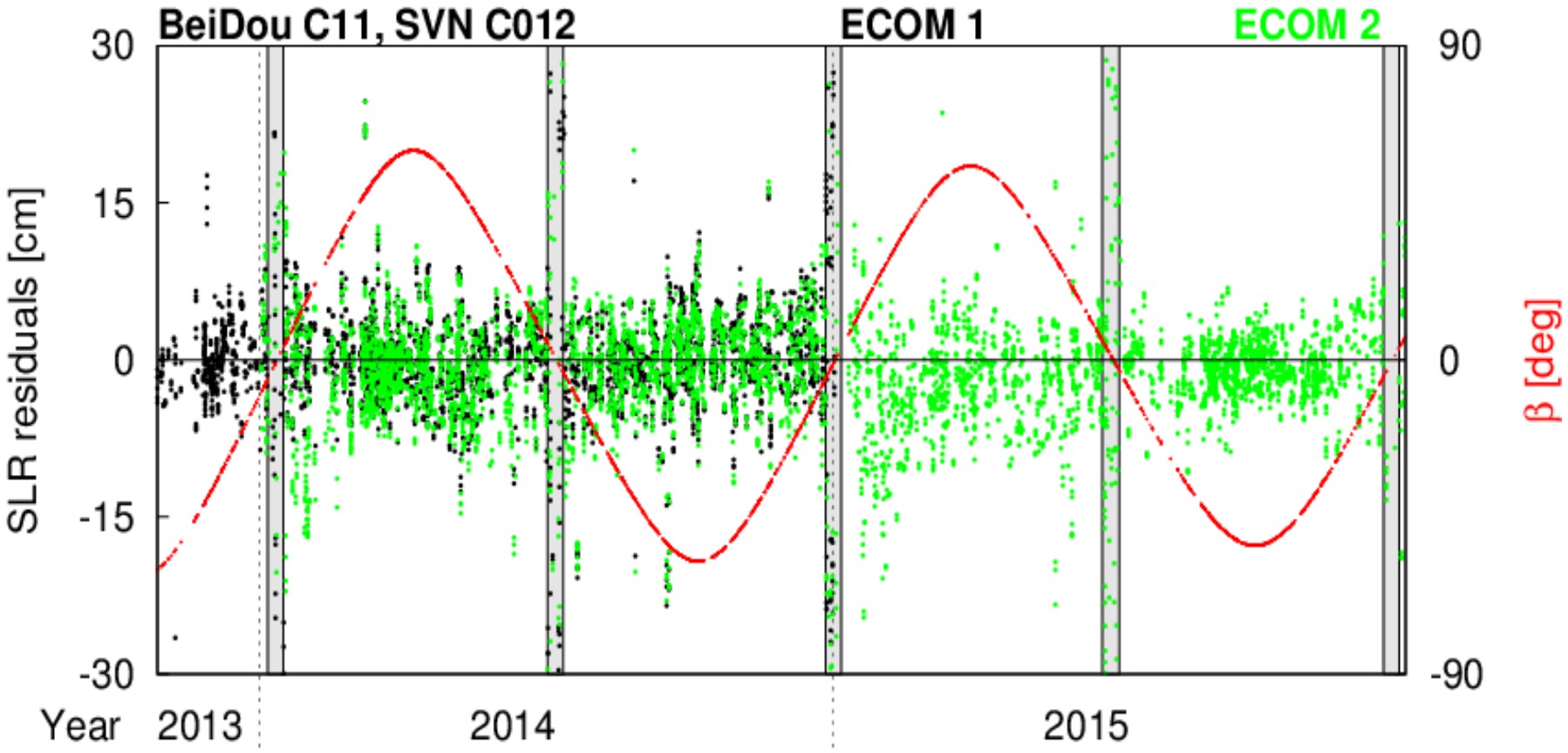
Impact of new ECOM on QZSS clock corrections



⇒ Significant reduction of Beta angle dependency at Yaw attitude thanks to ECOM2

⇒ Experiments with ECOM version suited for normal attitude mode

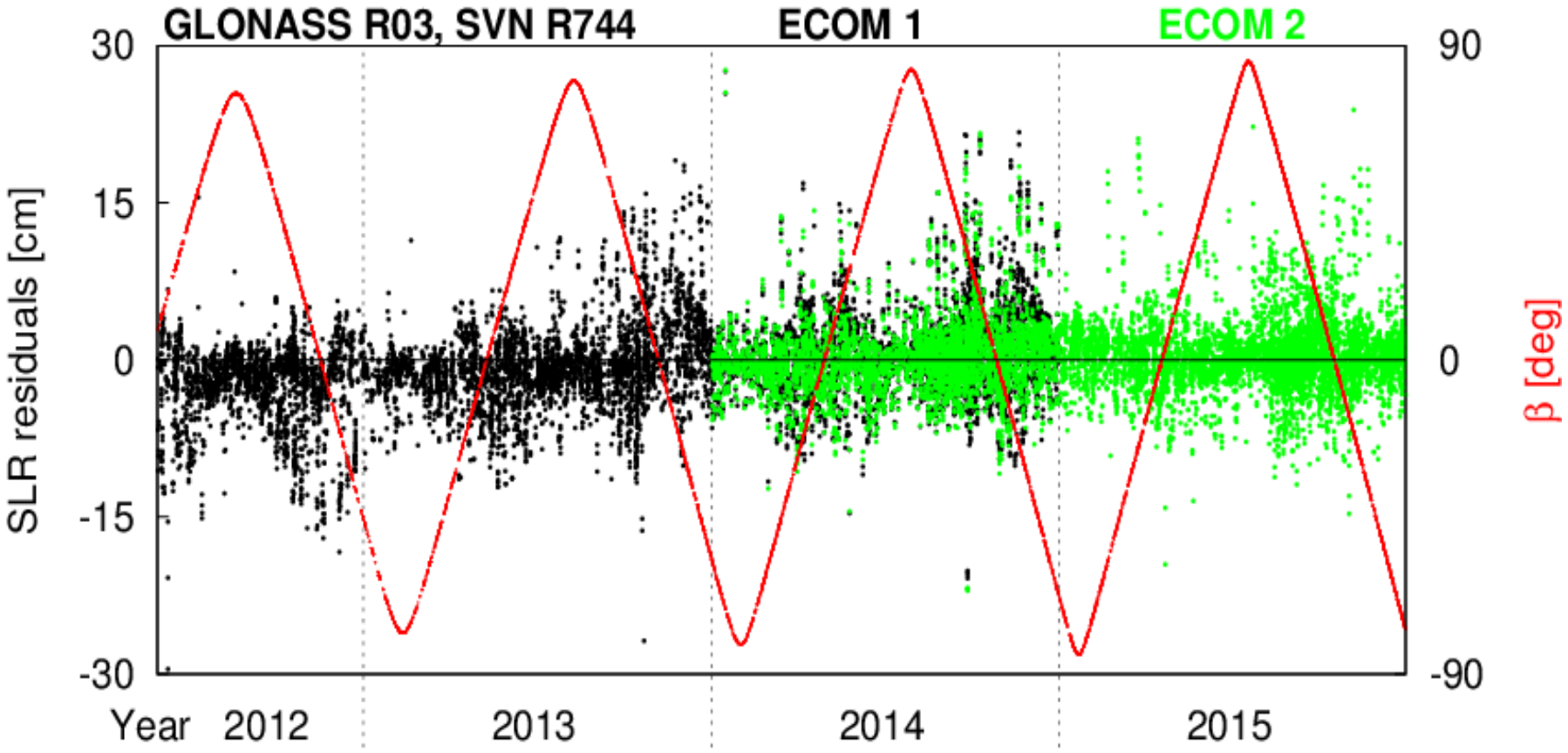
Impact of new ECOM on BeiDou orbits



⇒ No significant impact of new ECOM on BeiDou orbits

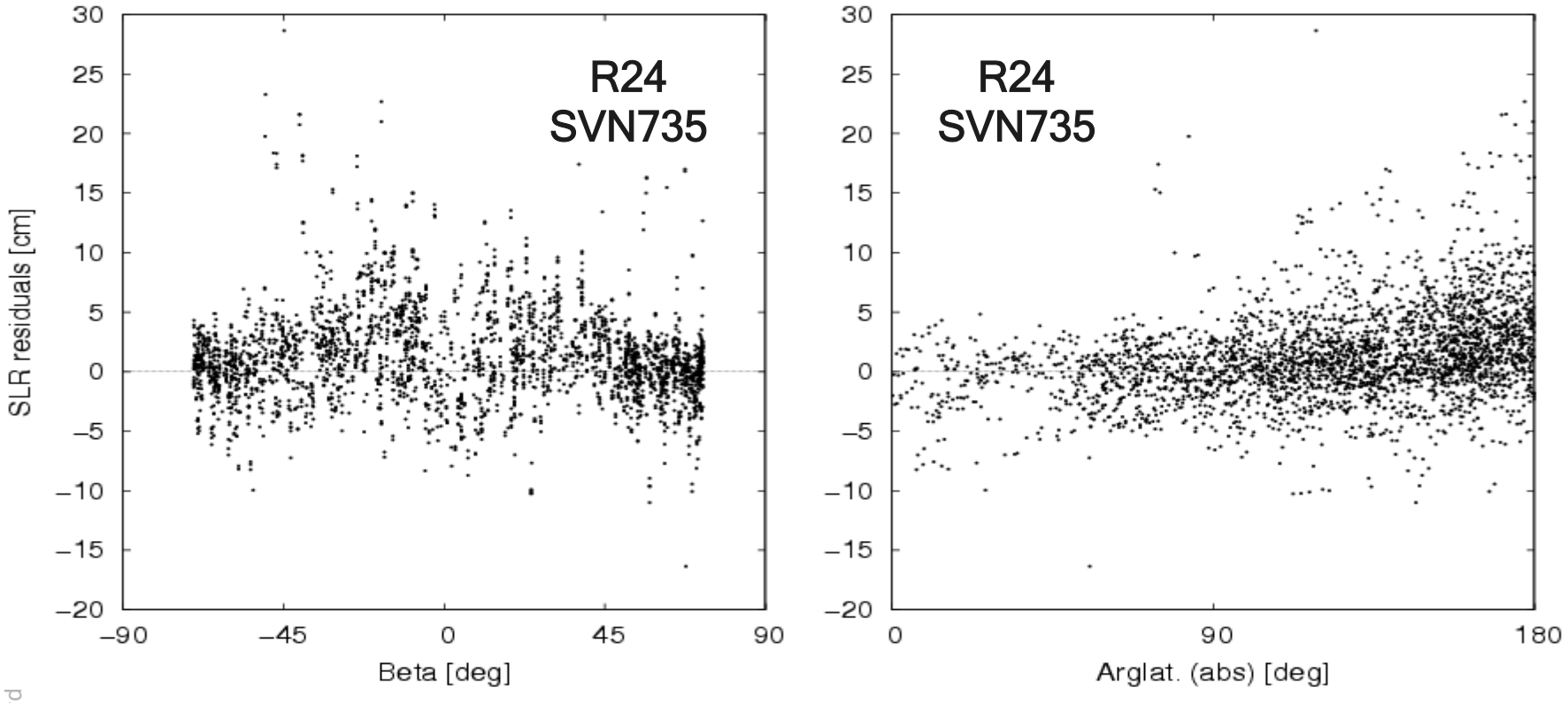
⇒ Large residuals for |ß| < 4° (marked grey), because orbit normal attitude not yet correctly considered

Impact of new ECOM on GLONASS orbits



⇒ Moderate reduction of SLR residuals at low Beta angles for majority of GLONASS satellites

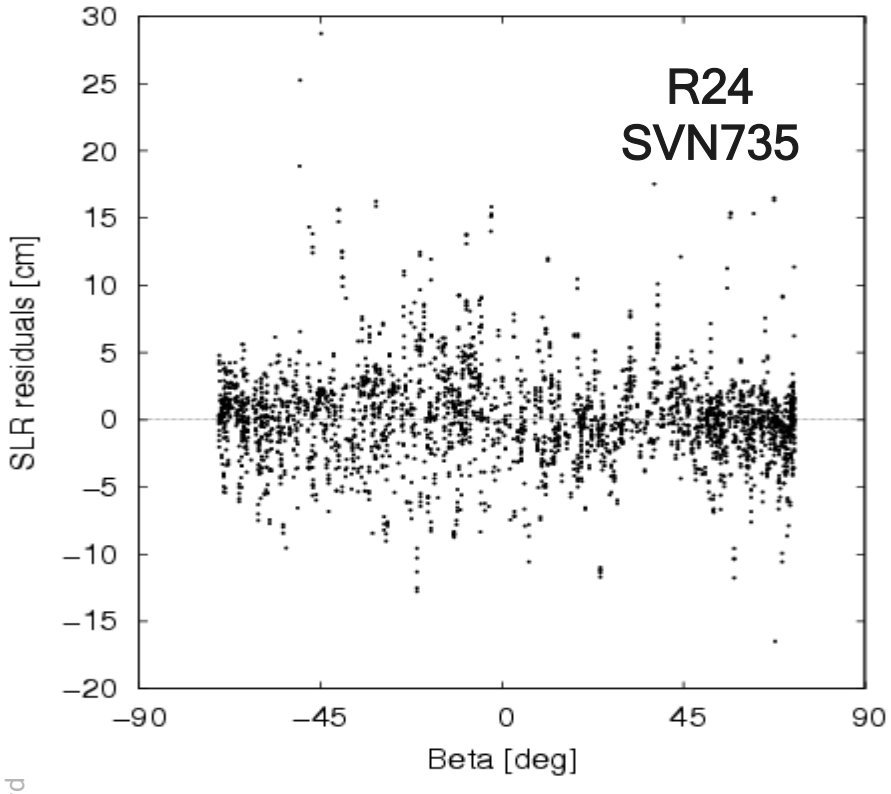
Impact of new ECOM on GLONASS orbits

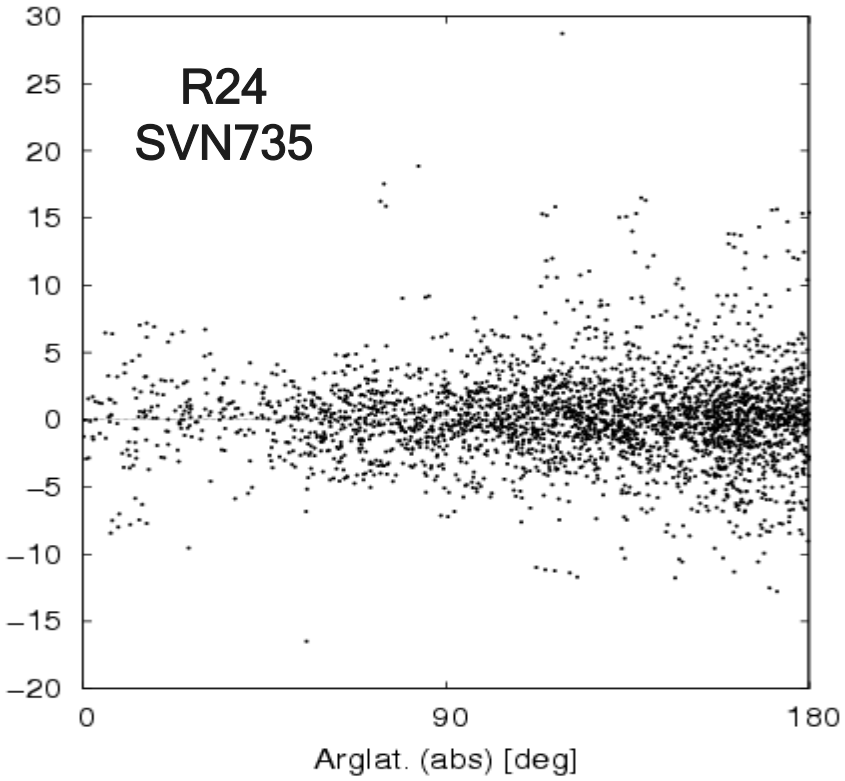


ECOM1:

⇒ Moderate correlation of SLR residuals from 2014 with Beta angle and argument of latitude

Impact of new ECOM on GLONASS orbits

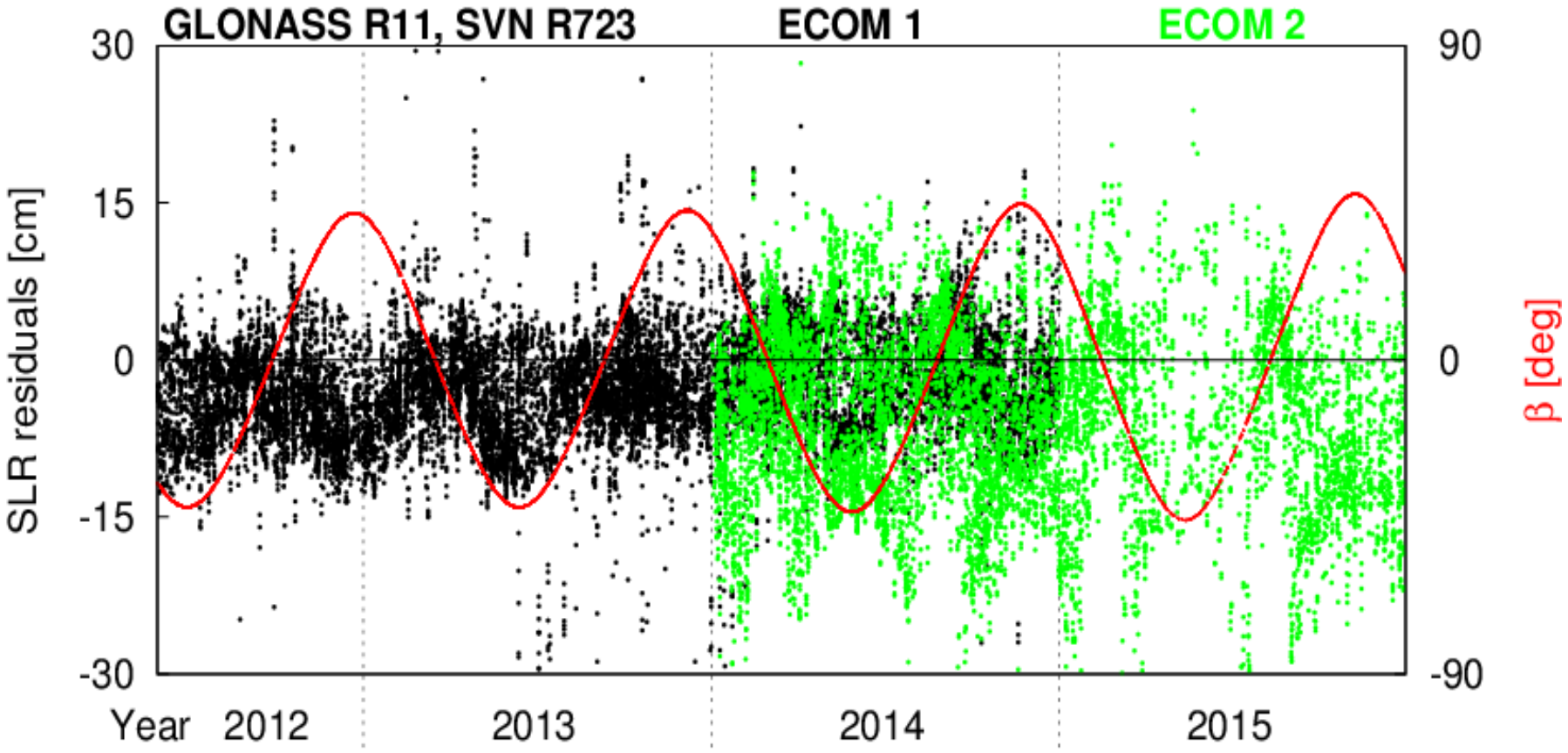




ECOM2:

⇒ Systematics in the SLR residuals are reduced for most GLONASS satellites

Impact of new ECOM on GLONASS - exceptions



But: ECOM2 does not work well for all GLONASS satellites (related to attitude issues?)

Summary

- Galileo, QZSS: significant improvement of orbits and clocks with ECOM2, when in yaw-attitude
- GLONASS: moderate orbit improvement with ECOM2 for the majority of satellites; degradation for some satellites
- ECOM2 is possibly more sensitive to attitude mis-modellings (compared to ECOM1)
- Normal attitude steering mode at low beta-angles causes very large orbit errors if not correctly considered
- Stable satellite clocks (GPS IIF, Galileo PHM, QZSS) are well suited for orbit validation
- Reprocessing of data from 2015 planned

Thank you

for

your interest!